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ABSTRACT

This unit developed by the Third World Science Project, is designed to add a multicultural element to existing science syllabi (for students aged 11-16) in the United Kingdom. The project seeks to develop an appreciation of the: boundless fascination of the natural world; knowledge, skills, and expertise possessed by men/women everywhere; application of knowledge and skills to solve the practical problems of everyday life; impact of modern technology in the world; and the influence of the cultural background on the perception of knowledge, problems, and solutions. The unit begins with a discussion of the structure and fermentation activity of yeast (Saccharomyces), followed by an account of Pito brewing in Northern Ghana. Main concepts and processes arising from each step in the brewing procedure and the industrial manufacture of the beverage are included. The brewing of Kanchine (Zambian beverage) is then considered, including rules for drunkards. The unit concludes with four experiments focusing on anaerobic respiration and fermentation in yeast. Laboratory procedures, materials needed, and related questions are included for each experiment. (JN)

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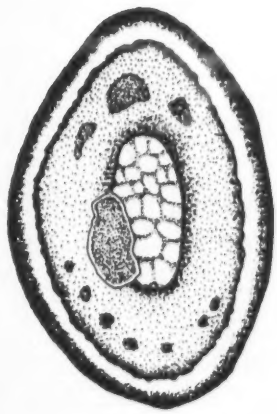

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FERMENTATION

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THIRD WORLD SCIENCE

Third World Science seeks to develop an appreciation of:

1 The boundless fascination of the natural world

2 The knowledge, skills and expertise possessed by men and women everywhere

3 The application of knowledge, skills and expertise to solve the practical problems of everyday life

4 The impact of modern technology in the third world

5 The influence of the cultural background on the perception of knowledge, problems and solutions

The following Units have been designed to fit into existing science syllabuses in the United Kingdom:

CARRYING LOADS ON HEADS: CHARCOAL: CLAY POTS:
DENTAL CARE: DISTILLATION: ENERGY CONVERTORS:
FERMENTATION: HOUSING: IRON SMELTING: METHANE DIGESTORS:
NATURAL DYES: PLANTS AND MEDICINES: SALT: SOAP.

The method of use is not closely prescribed. As resources teachers may use them in different ways though suggestions are offered. Feedback is invited from teachers concerning (a) the use made of the material (b) pupils reactions, if possible in their own words, and (c) suggestions for improvements, additions etc.

Please send feedback, ideas and requests to:

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FERMENTATION

Teacher's Notes

We felt it necessary to begin this unit with a brief account of the Yeast cell and the basic principles of fermentation. This is followed by an account of Pito brewing in Northern Ghana described by Mr. J.M. Yakubu, Bagabaga Training College, Tamale, where the way of life of the Kuasi tribes is intensely impregnated with scientific concepts. The science specialist student is required to work on a project based on one of the activities in the environment, such as Pito brewing - described in this unit. The student then identifies the scientific concepts involved in various stages of the process.

The section on Kanchine brewing was contributed by third year pupils of Lubushi Seminary, Northern Zambia.

The unit concludes with a section on some suggested class activity.

FERMENTATION

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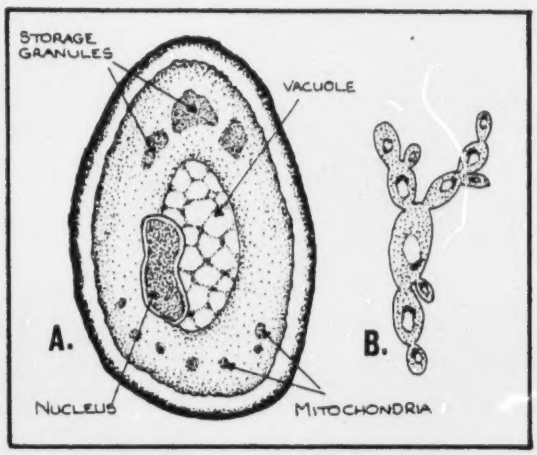
FERMENTATION

Yeast is a fungus - *Saccharomyces* - which man has used for centuries to produce alcohol and to make bread. *S. cerevisiae* occurs as a wild yeast, but it also has many industrial and domestic strains that have special properties useful to man and that have been selected for particular purposes. Brewers' yeast, bakers' yeast, and wine yeasts are all strains of *S. cerevisiae*.

The yeast cell is oval with a firm cell wall. At one side of a large vacuole in the cell is a dense nucleus. Reserve material occurs in the cell as glycogen and oily materials. Growth occurs by an overall increase in cell size, until eventually vegetative reproduction takes place. This begins by a bud blowing out at one end, and when this reaches about half the size of the parent cell, the parent nucleus divides, and with it the vacuole. One half of each passes into the bud which becomes pinched off, leaving a scar on both cells. Further growth of the parent cell, which is already at its maximum size, results in the production of another bud at the opposite end to the first. By repetition of this process, known as *bipolar budding*, a spiral series of bud scars is formed at each end of the parent cell and these indicate how many buds it has produced.



A. Cell.
B. Pseudomycelium – showing bipolar budding.

In a well-aerated solution with ample nutrients the yeast multiplies rapidly by budding and has the normal aerobic metabolism that is represented overall by the equation:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

With very rapid growth the cells may fail to pinch off completely before the daughter cells themselves produce further buds (See drawing). In this way bead-like branched chains of cells develop.

The growth rate decreases and budding is almost non-existent in the absence of an adequate oxygen supply. However the cells can metabolise anaerobically as represented by the equation:

$$C_6H_{12}O_6 \longrightarrow \underset{\text{ethanol}}{2C_2H_5OH} + 2CO_2$$

This process is *fermentation* resulting in the production, of ethanol and carbon dioxide which are essential for some of the different domestic and industrial functions of yeast.

The fermentation of yeasts provides the basis of all alcoholic beverages e.g. in wine production, grape juice is the sugar source, while suitable nitrogenous compounds, vitamins and minerals provide the essential growth nutrients.

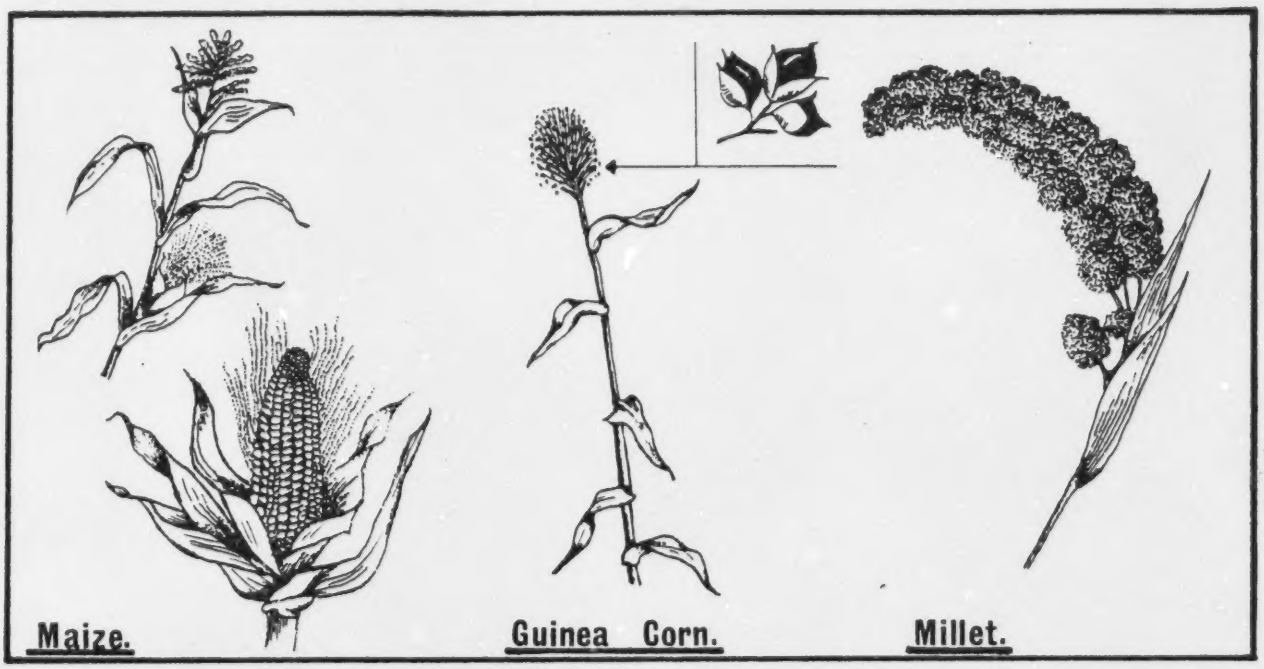
Suitable strains of yeast usually exist on the skins of the fruit and in the early stages of fermentation when oxygen is present, the inoculum grows to produce large colonies of cells. The anaerobic process takes over when the dissolved oxygen has been exhausted resulting in the formation of alcohol and carbon dioxide. Fermentation continues until approximately 12-16%, by volume of alcohol has been produced, after which further activity ceases because the solution becomes toxic to the yeast cells. The strain of yeast, the initial concentration of sugar and other nutrients are all factors which will affect the acutal level of alcohol in a wine.

When fermentation ceases the cells settle to the bottom as *lees* and the wine becomes clear. The wine is allowed to mature slowly - this depends on a slow oxidation of alcohols to acids, and combination of these acids with alcohols to produce esters.

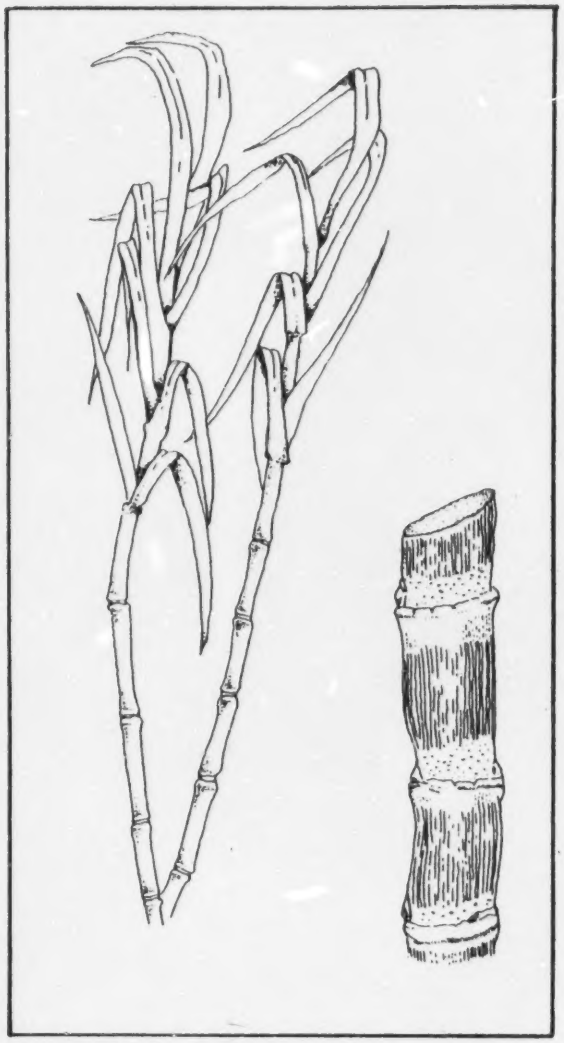
The starch in barley grains provides the raw material for beer making. The enzyme *amylase* is lacking in yeasts and so they are unable to hydrolyse the starch to glucose. Consequently the barley grains are first malted i.e. the grains are allowed to germinate under controlled conditions thus activating their hydrolysing enzymes. The germination is halted before much of the starch has been changed, by heating to a temperature which does not damage the enzymes. *Malt* is formed when the grain is dried and ground. The *amylase* converts the starch to glucose when the malt is mashed with warm water, after which the process if stopped by heating.

The clarified fluid from the mash is then boiled with hops, and then cooled to fermentation temperature in a fermentation tank. The fermentation is started by adding yeast. The hops contain resins which precipitate the proteins that cause cloudiness, and so help in the clearing process. The resins are thought to give the beer a characteristic astringent flavour as well as conferring some preservative action against bacterial action.

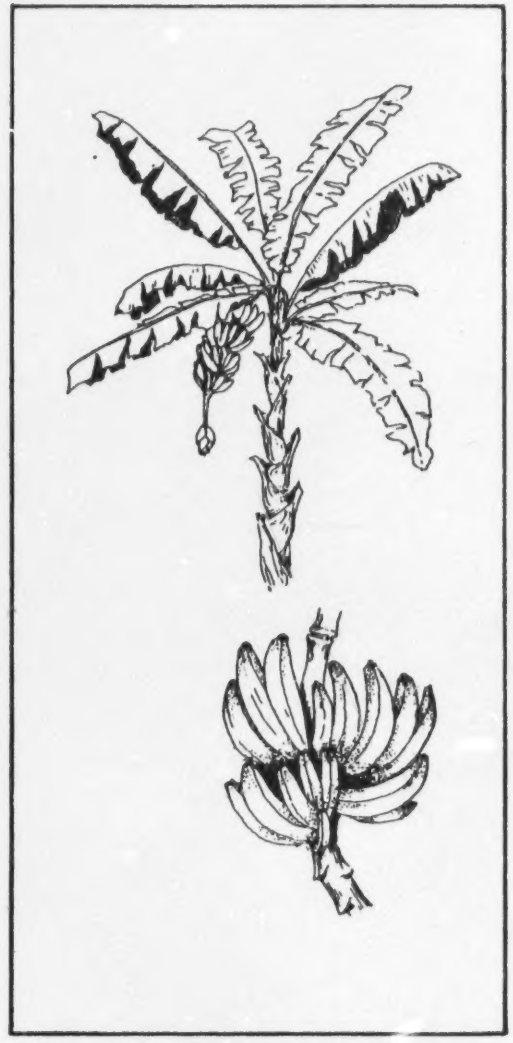
All over the world man has realised that if sugary substances are left for some time they will be converted naturally into alcoholic drinks, sometimes yeast is added to speed up the process. In Africa a variety of foods are fermented to produce beers. These include maize corn, guinea corn, millet, sugar cane, banana (or plantain which is of the banana family) and palms.



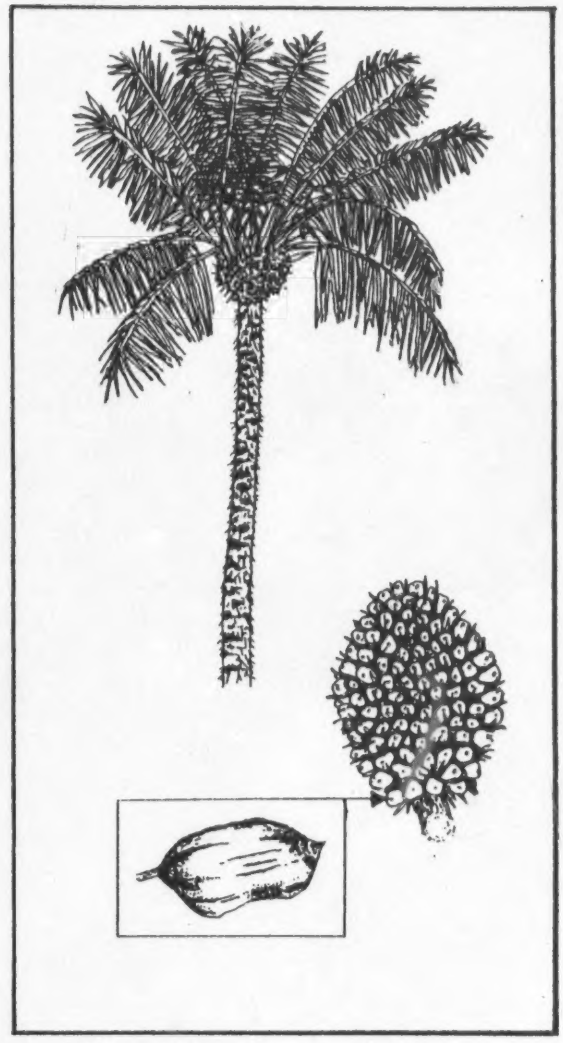
Alcohol is an immediate source of energy to the body due to its rapid oxidation into non-toxic products; this is regarded as a useful addition to the diet of malnourished people living in famine areas. In Uganda ripe sugar cane is fermented to produce an alcoholic drink called *Kkangala*. In West Africa old palm trees are cut down and the tree sap is allowed to ferment inside the bark to produce an alcoholic drink called 'palm wine'. In the North of Ghana the cereals guinea corn and millet are used to make the brew called 'pito'.



Sugar Cane.



Banana (Plantain).



Oil Palm and Fruit (Bangas).

PITO BREWING IN NORTHERN GHANA

1. The guinea corn is spread onto a clean floor and sprinkled with sufficient water to allow for germination which takes about three days. The germinating corn is then dried in the sun and becomes the malt — GERMINATION

2. The dry malt is ground into powder and soaked in water in large earthenware jars for about one hour. — SOLUTION

3. The solution is mixed well with the aid of okra stalks which have been powdered into a pulp. This solution is allowed to settle for one hour during which time a sediment forms. — SETTLING

4. The clear solution is decanted into sets of earthenware pots and the sediment is added to another set of pots. All the pots are boiled for three hours by a fire. — DECANTING

6. The next morning the solution should taste sour, and if so the solutions are transferred into the storing jars again for further sedimentation and cooling. The solution which contains the solid particles is then filtered.

7. The filter is made of grass and the filtrate is then transferred to another set of storing jars for cooling and further sedimentation.

8. Decantation continues as a clear solution is obtained, and a thick sugary sediment is left. This is discarded, or drunk by children as a source of food. — FILTRATION

9. A sample of clear solution is put into an open earthenware bowl, the temperature is tested with the finger and when the liquid is cool enough yeast is added and left overnight to ferment. TEMPERATURE

10. The next morning portions of the yeast culture are taken from the bowl and added to the large pots of clear solution which have cooled sufficiently. Fermentation occurs in these pots throughout the day and frothing pito is ready for serving to customers the following day. The pito is traditionally served in half a hollowed-out gourd called a 'calabash'. FERMENTATION

No two pitos taste the same and the success or failure of the pito depends very much on the expertise of the pito brewer who is totally unaware of the biological and chemical processes which are occuring during her work. One attempt has been made to produce pito commercially in Ghana, the bottled pito was sold under the brand name of 'Tiger Pito'. Unfortunately 'Tiger Pito' did not taste too good because the commercial process did not follow the traditional process and the venture was a failure.

MAIN CONCEPTS AND PROCESSES ARISING FROM EACH STEP

1) During germination of the guinea corn a lot of diastase enzymes are produced for the hydrolysis of starch to maltose and the other sugars. The corn is dried to prevent the conversion of too much starch into maltose at this stage although the enzymes remain intact.

2) In warm water the diastase is very active and there is rapid hydrolysis of the starch into maltose and other sugars.

3) The mixture is stirred with okra stalks because these slimy plants help particles to settle out of suspension.

4) The boiling process helps to dissolve the sugars and to kill off any germs which may be present at this stage.

5) During the settling overnight, bacteria will be cultured and this will give the solution a sour flavour in the morning.

6) The long boiling kills the bacteria and brings out the full flavour of the ingredients.

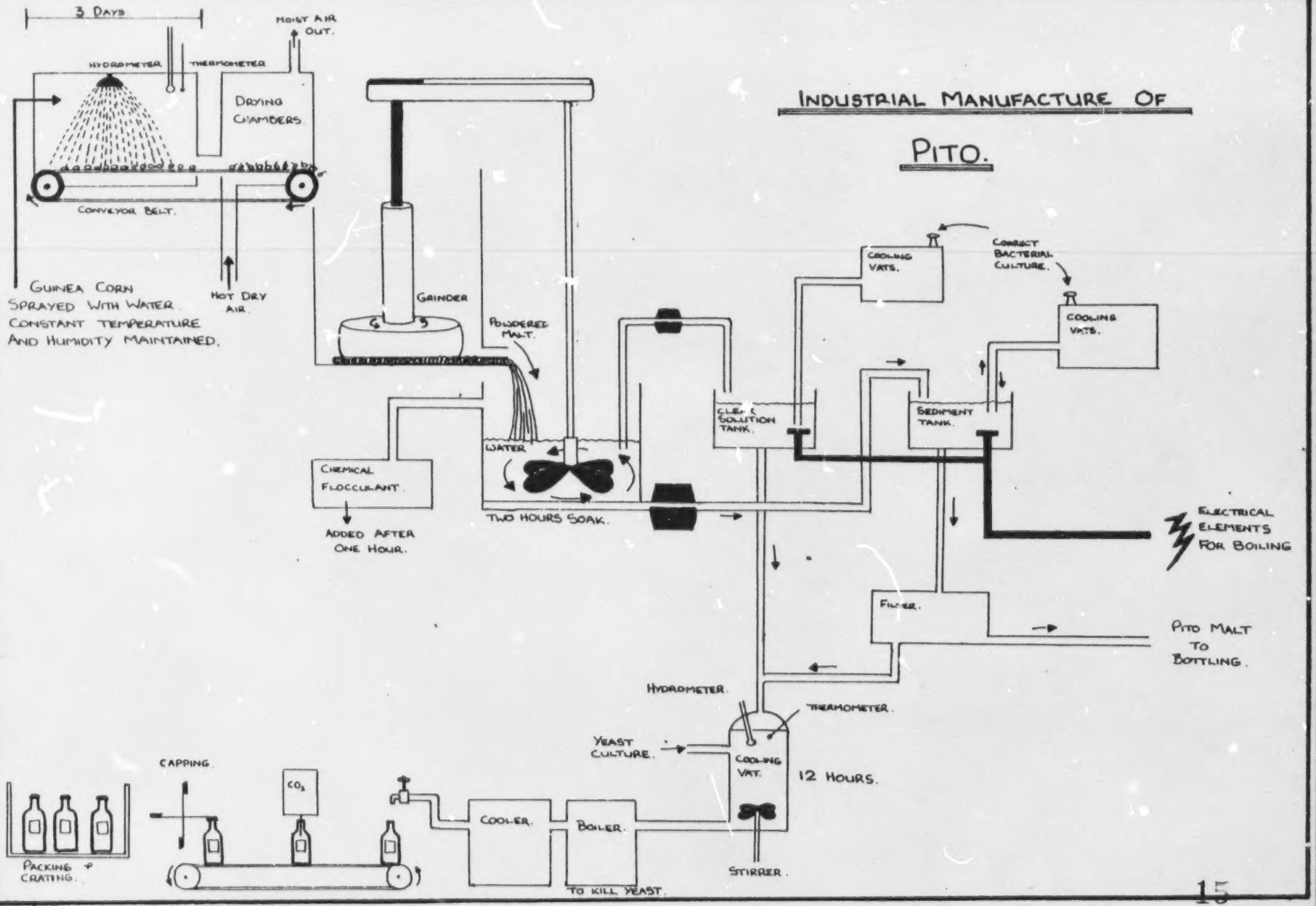
7) At this stage the solids are separated from the liquid by filtering.

8) The sediment or pito mash is rich in protein and a useful source of nourishment for children and domestic animals.

9) A finger is used as a thermometer to test for the temperature which should be around 40°C for the Saccharomyces yeast to thrive and to commence the fermentation.

10) During this last process most of the maltose is converted to alcohol by fermentation.

INDUSTRIAL MANUFACTURE OF PITO.



Contribution made by 3rd Year Pupils of Lubushi Seminary, Northern Zambia.

KANCHINE BREWING

Kanchine is the name given to this alcohol, because of its strength.

Requirments

1. A certain amount of maize depending on the quantity of alcohol he/she wants to produce.
2. Cassava mealie - meal of the same quantity as that of maize.
3. A pipe for distillation.
4. A tin or a drum depending again on the quantity needed.
5. A bottle for collecting the distilled alcohol.

Explanations

1. A certain amount of grain maize has to be collected. This amount is then submerged in water until it becomes soft. The amount of maize has to be in water for at least a week. After it has been puffed up, it is taken out of water and heaped somewhere in the house. Again the amount of maize has to be in the house for two weeks so that it can germinate. When it germinates, it is moved from the house and be spread over a mat to get dry.

At this time, when the maize is dry, it becomes black. It is then pounded and preserved until Cassava mealie-meal is found.

2. As cassava mealie-meal is found, it is then made into a dough - not too strong. The dough which is made is then mixed with the pounded crushes of maize. The amounts must be the same. Mixing of cassava mealie-meal and the pounded maize mealie-meal is done into a drum or a tin with warm water to lessen the thickness of the dough. When this is done, a lid is pressed on the tin or the drum leaving no space for air to go in.

Fermentation

Then the drum or tin of the mixture is put back into the house for about a week so that the mixture is fermented. When it is fermented it is taken outside. A pipe is fixed in the drum and welded around it so that the steam cannot escape through spaces left. The pipe passes again through a tin containing cold water (condenser) to a bottle. This is done before the drum is set on fire. NO yeast is added to the mixture, but cassava mealie-meal and the crushed maize mealie-meal react with each other.

The fermentation itself is done to decompose the organic substances by organisms, especially the bacteria.

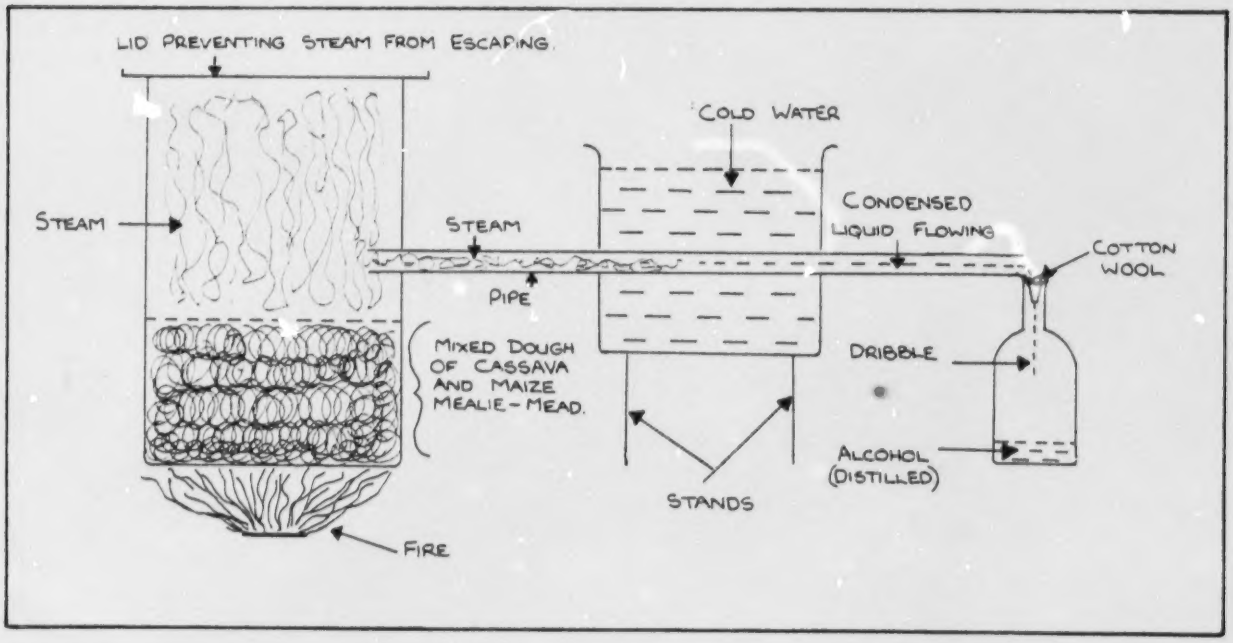
Distillation

As far as the getting of complete pure alcohol from mixed substances is concerned, the alcohol is got by a process of distillation. The dissolved impurities and germs left behind when the steam rises.

Distillation involves two processes. First, of steam rising filling the space in the drum, and of condensation, that is steam from the drum flows along the pipe, comes to the condenser where it is turned into a liquid and finally flows to the bottle. When the alcohol is very strong it will burn with a blue flame.

The condenser should be on a stand or a box so that it remains at the same level with the pipe. To remove impurities which flow together with the condensed liquid, a piece of cotton wool is put at the end of the pipe through which the liquid passes.

. The liquid that collects in the bottle is the real strong alcohol.



Rules for Drunkards

1. If a man drinks to excess, he must not be allowed to go swimming because if he goes the chances are that he will die, even in shallow waters. This is because the alcohol reacts very strongly in a human body, and more especially in a chest. The chest becomes so hot that a person is forced to dip himself into the water. He does not only dip himself into the water, but due to the coolness of the water, he prefers to lie in water, and when he lies in water the chances are that he will take water through his nostrils and die.

2. It has been proposed by Kanchine brewers that if a person is too drunk, his people or her people should make him porridge so as to reduce the reaction. When he eats the porridge, he or she will immediately be well again.

This kind of beer-brewing is mainly practised among the Lungu and the Tabwa peoples, but it is also brewed by other people other than both the Lungu and the Tabwa.

The brewing of this alcohol will soon be abolished, because most people die when they are drunk and not looked after.

From where we get the Information and Advice

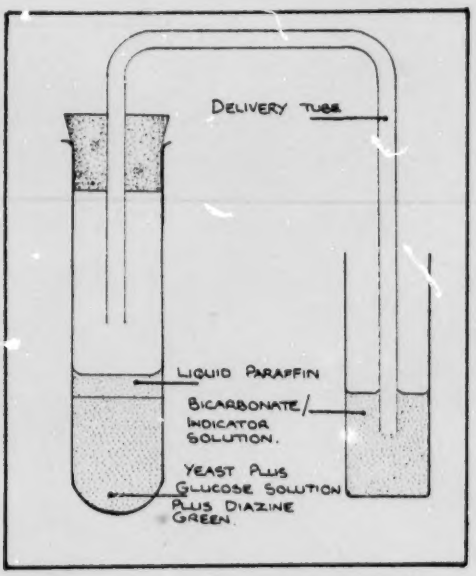
We consulted Mrs Mazimba at home, Mrs Ruth and Mrs Alas of Kapoko village and we were told the same principles. The consultations of these people were made during the holidays in April, 1976. We spent one full week making experiments. We also attended the process in the village wherever Kanchine was to be made so as to observe very carefully what the women did. Some precautions were taken especially in controlling the water in the condenser whenever it became hot, cold water was poured into the drum.

CLASS ACTIVITY

EXPERIMENT 1: Anaerobic Respiration in Yeast

Yeast is a micro-organism which can respire in two ways. You can investigate some aspects of this in a simple experiment. The indicator, *diazine green*, changes colour according to the amount of oxygen present;

Oxygen present	*Oxygen absent*
Indicator oxidized to *blue* colour	Indicator reduced to *pink* colour



1. Place 20 cm^3 of glucose solution with some yeast added to it in a test-tube. Add 2 drops of diazine green solution. The colour produced will tell you whether oxygen is present in the mixture.

2. Pour enough liquid paraffin over the mixture to form a layer right over the surface. This layer will prevent more oxygen form the air from getting into the mixture.

3. As soon as the colour of the mixture indicates that there is no oxygen present, fix up a delivery tube leading to a small amount of bicarbonate/ indicator in another test-tube. (See above)

4. Design and set up a suitable control. Remember that in this experiment you are trying to find out whether the yeast is respiring in the absence of oxygen.

5. Leave the apparatus for 10-20 minutes and then record your observations.

Questions

1. What can you conclude from the final colours of :-

   a) the bicarbonate/indicator solution, and

   b) the *diazine green* solution?

2. What can you conclude from your answers to question 1?

EXPERIMENT 2 - FERMENTATION

If yeast is left in a sugary liquid for some days, a characteristic smell is produced. This is the result of *ethanol* accumulating in the mixture. *Fermentation* is the name given to this process in which yeast turns sugar into ethanol.

Suggest a way of discovering whether energy is released during this process.

1. Prepare 2 balls of cottonwool, each about 1 cm across.
2. Place one on an asbestos mat. Light it with a match and time how long it burns.
3. Place the second ball on the mat. Add 2 drops of ethanol to it. Light this ball and time how long it burns.

Questions

1. Apart from the duration of burning, was there any difference in the burning of the two balls of cottonwool?
2. What does this experiment tell you about the energy conversions during the anaerobic breakdown of sugar to ethanol?
3. Can you suggest a reason why most cells do not respire anaerobically at all times?

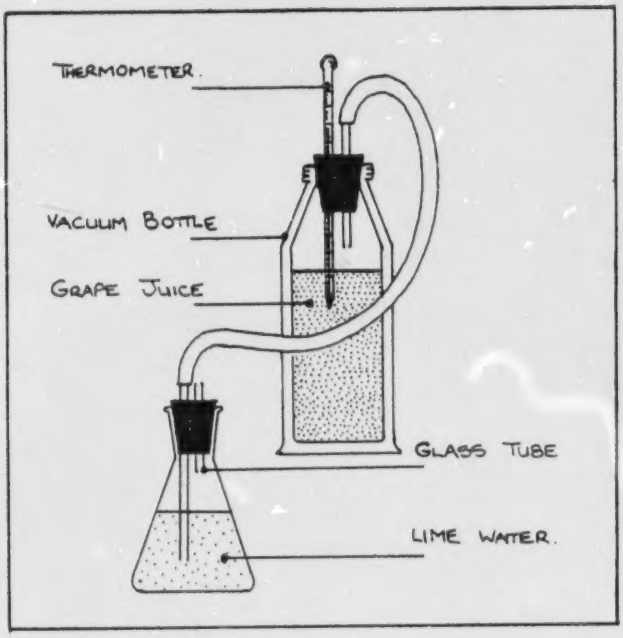
EXPERIMENT 3 - FERMENTATION ON A SMALL SCALE

Requirements:- Millet Seed (from pet shops)
Yeast
Winemaker's Sedimenting Powder (optional)

Method

1. Spread the millet seed on some damp tissue paper in a seed tray. Sprinkle with water and place in an incubator at about 36°C for 3 days until the seed has germinated
2. The millet is then ground to a powder and soaked in some water in a beaker and left for about one hour.
3. The solution is then mixed with some winemaker's sedimenting powder and allowed to settle for one hour. (This stage may be omitted)
4. The clear solution is then decanted into one beaker and the sediment is placed in another beaker. Boil the solutions for about 45 minutes (depending on the quantity) until reduced to about half the original amount.
5. The solutions are then poured into larger containers which are covered and allowed to settle overnight.
6. The clear solution is then decanted and placed in an open earthenware bowl and enough yeast is added to it to ferment overnight.
7. When the frothing has ceased fermentaion has been completed.

EXPERIMENT 4 - INVESTIGATING FERMENTATION by YEAST CELLS



Materials

2 Vacuum bottles or Thermos flasks
2 two-hole stoppers for vacuum bottles
2 50 mls flasks each with 25 ml limewater
2 two-hole stoppers for flasks
4 short pieces of glass tubing
Rubber tubing
2 thermometers
Grape juice
1 Yeast cake
Stirring rods
Microscope
Slides
Cover slips
2 droppers

Method

1. Set up the apparatus as shown above.
2. Pour grape juice into both vacuum bottles leaving about a 7.5 mm space. To one, add half a cake of crumbled yeast. Label the vacuum bottles to identify the one that contains the yeast. Stir well to distribute the cells and mount a drop of the liquid from each bottle on a slide for microscope study. Observe under both low and high magnification and draw a few cells as they appear under high power. Note about how many cells you can see in the high power field of vision.

3. Place the stoppers in the vacuum bottles. The thermometer but not the glass tubes should dip into the liquid. Then place the stoppers in the flasks. Each longer glass-tube should extend below the surface and each of the other glass tubes should end above the liquid. Using rubber tubing, connect the glass tube coming from the vacuum bottle assembly to the longer glass tube in the flask assembly.

4. Record in a table the temperature of each bottle. Continue recording each hour for the remainder of the school day, and again the following days until 48 hours have passed. Note other changes that happen during the 48-hour period.

5. At the end of the 48-hour period, open both vacuum bottles and compare the odour of their contents. Stir the contents of each bottle with a separate stirring rod. Using separate droppers transfer a drop of the liquid from each bottle onto separate microscope slides and cover with cover slips. Observe under both magnifications. Sketch a few cells as seen under high power. Note the approximate number of cells in the high-power field.

6. Plot rough line-graphs from the temperature data collected. Draw the lines for both sets of readings on the same graph. Use the horizontal axis for time and the vertical axis for temperature.

Discussion

1. What evidence is there that a chemical change has taken place?
2. What by-product of fermentation is indicated by the limewater reaction?
3. What by-product can be detected by the odour?
4. The set-up of the apparatus suggests that oxygen is not being supplied to the system from the air. What activity supports the idea that a constant supply of atmospheric oxygen is not necessary for this process?
5. What quantitative data does your graph show? State a hypothesis that would explain the changes shown by the graph.
6. How does the appearance and number of the yeast cells change during the experiment? Does this change support the hypothesis that fermentation is an energy-releasing process?
7. C_2H_5OH is the chemical symbol for alcohol, and CO_2 stands for carbon dioxide. What material in grape juice was converted into these products?

References

1. Science Teacher (London vol. 20. No's 1 & 2, 1976, pp. 10-13) - Influence of Culture on Learning and Teaching of Science in Northern Ghana - J.M. Yakubu, Bababaga Training College, Tamale.
2. Biological Science - Molecules to Man - Prepared by - The Biological Sciences Curriculum Study.
3. Lowson's Textbook of Botany - Revised by Simon, Dormer and Hartshorne.
4. Living Things in Action - Revised Nuffield Biology - Text 2.

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